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UPGRADE OF THE MUON SORTER IN THE CATHODE STRIP CHAMBER LEVEL 1 TRIGGER SYSTEM AT CMS

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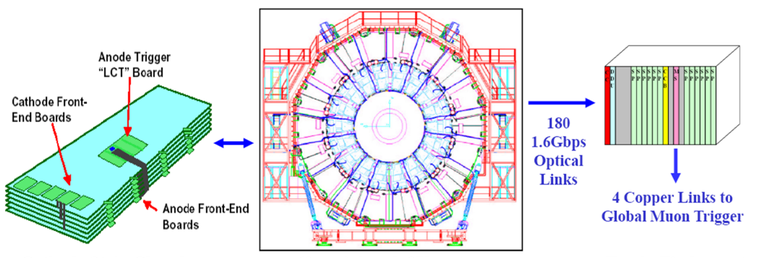
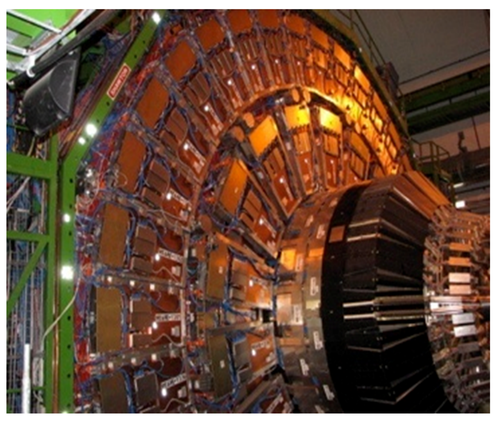
ENDCAP MUON (EMU) CATHODE STRIP CHAMBERS AND TRIGGER ELECTRONICS



Chambers and On-chamber Electronics

- 473 trapezoidal 6-layer multi-wire proportional chambers (540 after upgrade)
- Located in the endcap regions of CMS and arranged in four stations ME1/2/3/4
- Intended for muon identification, triggering and momentum measurement
- Each chamber is equipped with:
  - 4 or 5 Cathode Front-End Boards (CFEB)
  - 12..42 Anode Front-End Boards (AFEB)
  - One Anode Local Charge Track (ALCT) Card

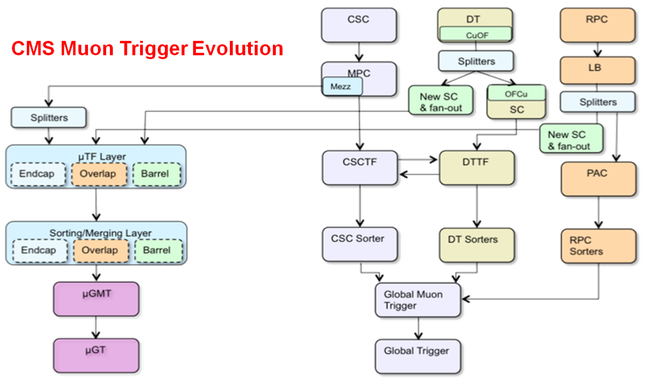


Endcap Cathode Strip Chambers (CSC) at CMS

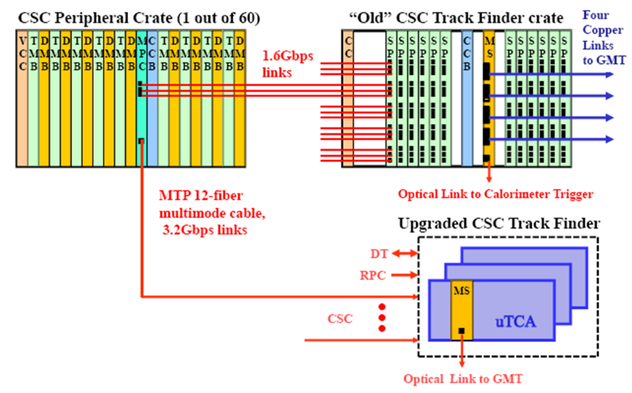
EMU Trigger Electronics

- Anode and Cathode track segments called Local Charged Tracks (LCT) are found independently using pattern recognition firmware
- ALCT and CLCT are combined in the Trigger Motherboard (TMB). Each chamber is served by one TMB.
- 60 9Ux400 mm VME crates are located on the periphery of the return yokes of CMS. Each crate houses:
  - Up to 9 Trigger Motherboards (TMB)
  - Up to 9 Data Acquisition Motherboards (DMB)
  - One Muon Port Card (MPC)
  - One Clock and Control Board (CCB)
  - One custom VME Crate Controller (VCC)
- Up to two combined anode/cathode LCTs are sent from each TMB to the MPC over point-to-point backplane lines in the peripheral crates.
- MPC performs sorting (based on 4-bit "Quality" value of the LCT), selects the three "best" LCTs and transmits them to the Sector Processor in the Track Finder crate in the underground counting room.
- The Track Finder crate comprises:
  - 12 Sector Processors (SP)
  - One Muon Sorter Board (MS)
  - One Clock and Control Board (CCB)
  - One Detector Dependent Unit (DDU) Card
  - One CAEN V2718 VME Crate Controller
- On top of the CSC Trigger chain, the Muon Sorter selects 4 "best" muon patterns and transmits them to the Global Muon Trigger receiver board at 40MHz via dedicated copper links

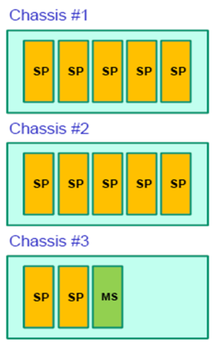
CSC TRACK FINDER UPGRADE GOALS



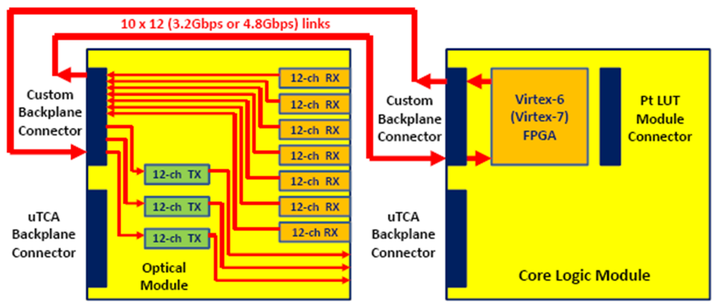
- CSC Track Finder Upgrade motivation:
  - robustness to high occupancy (remove the limit of 3 LCT per Muon Port Card)
  - improve Pt assignment
  - increase precision of muon output variables
  - recover "gaps" in coverage between trigger sectors
- "Old" and "New" Track Finders will operate in parallel between the LHC Long Shutdowns LS1 and LS2
- The Track Finder migrates from 9U VME to uTCA standard to take advantage of massive use of multi-gigabit serial copper and optical links



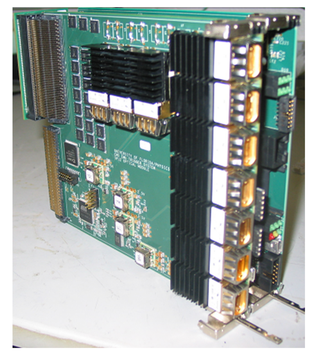
UPGRADED MUON TRACK FINDER HARDWARE



- Modular uTCA Track Finder (MTF):
  - will occupy 3 uTCA chassis
  - employ the same hardware for the SP and MS units
- MTF6 Processor comprises 2 boards connected via the custom 2-slot backplane bus:
  - Core Logic Module with the Pt Mezzanine Module
  - Optical Module
- MTF6 prototype is based on Xilinx Virtex-6 family. For the final design the target is a Virtex-7 family.



Muon Track Finder MTF6 Prototype Block Diagram and Picture



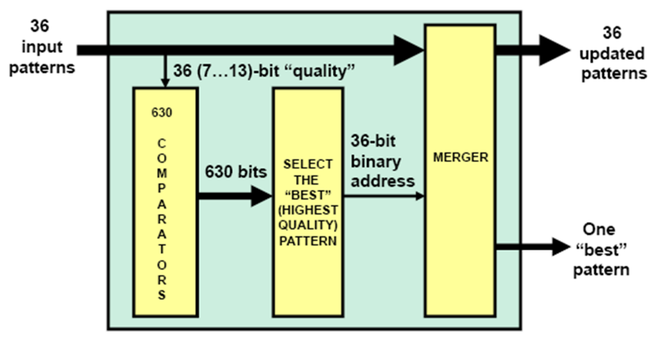
MUON SORTER HARDWARE AND FIRMWARE DEVELOPMENTS

Muon Sorter Inputs from the SP

Name	Description	Bit count, existing MS	Bit count, future MS
Eta	Pseudorapidity of the muon	6	9
Phi_outer	Outer ϕ of the muon	8	10
Phi_inner	Inner ϕ of the muon		10
Pt	Transverse momentum of the muon	5	9
Quality	Muon quality	3	4
VC	Valid charge flag	1	1
C	Charge (1=negative)	1	1
Halo	Halo muon flag	1	1
SE	Synchronization error	1	1
BC0	Bunch crossing zero flag	1	1
BX[2:0]	Lower three bunch crossing bits	3	3
Reserved	Parity and reserved bits	1	10
	Total bits per muon	31	60

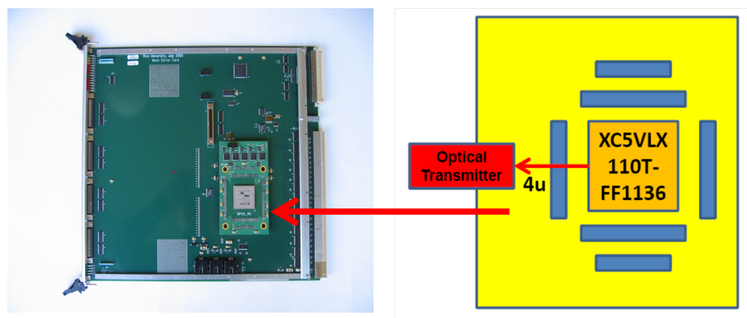
- 60 bits represent one "upgraded" muon from the SP12
- Each SP provides 3 muons to the Muon Sorter, or 180 bits
- At 3.2Gbps per link, every muon can be squeezed into one optical link (4 frames with 8B/10B encoding)
- Only 36 optical links (out of 84 available on MTF6) would be needed to implement the MS inputs
- 4..12 output optical links (out of 36 available on MTF6) at 3.2Gbps rate would provide outputs to the Global Muon Trigger

Sorting Algorithm and Firmware



- 3-step sorting (comparison > selection > merging)
- Modification of the existing algorithm for better scalability
- Sequential process to select (n) patterns out of 36 with very low latency for each step
- Compiled to Virtex-5 FPGA and the latencies are:
  - 50 ns for the sorter "4 muons out of 36"
  - 100 ns for the sorter "8 muons out of 36"
  - 150 ns for the sorter "12 muons out of 36"
- 7-bit and 13-bit "Quality" values were used

Interface to the Interim Calorimeter Trigger



- Targeting existing 9U VME Muon Sorter board
- Virtex-2 mezzanine board will be replaced with a new one with the Virtex-5 FPGA and optical transmitter
- 4 "best" selected muons are sent in parallel to the Global Muon Trigger (copper links) and to the interim Calorimeter Trigger so the forward muons can be isolated even before the full upgrade of the Trigger system is completed (during Long Shutdown 2)
- SNAP12 or QSFP optical transmitters can be used

CONCLUSION, FUTURE PLANS, REFERENCES

Conclusion

- The upgrade of the CSC Track Finder in general and its top component, the Muon Sorter board in particular, spans approximately for 6 years from the start of LHC Long Shutdown 1 (LS1) in 2013 till the end of Long Shutdown 2 (LS2) in 2018. At a fist stage during LS1 we plan to upgrade the mezzanine FPGA in the existing MS board as well as the FPGA mezzanines on all MPC boards that provide trigger primitives for the CSCTF. In addition to existing functionality the modified MS will provide an additional optical link to the "interim" calorimeter trigger for operation in 2015-2017. The Virtex-5 FPGA for this design has been identified and the schematic design of the new mezzanine is in progress.
- The CSC TF design is migrating from the 9U VME standard to a more flexible uTCA architecture with the emphasis on wider use of gigabit serial links. We expect that a fraction (slice) of the new TF will be ready by the end of LS1 and will be functioning parasitically in 2015-2017 in parallel with the old TF. We plan to build a new uTCA Track Finder in such a modular way that it will be able to perform all the Muon Sorter functions as well, eliminating the need to build a separate complex board. It will receive three reconstructed muons from each of 12 MTF boards and provide up to 12 pre-sorter muon patterns to the CMS Global Trigger; all inputs and outputs via optical links.

Future Plans

- Design of the new FPGA mezzanine for the existing VME Muon Sorter to provide an interface to the Interim Calorimeter Trigger: 2013-2014
- Integration tests of the slice of the new uTCA Track Finder at CERN: summer 2014
- Firmware design and commissioning of the uTCA Muon Sorter: 2015-1016

References

[1] M.Matveev, P.Padley. Upgrade of the CSC Endcap Muon Port Card at CMS. Published in Journal of Instrumentation 2010 JINST 5 C11013
[2] CSC Muon Sorter Specification: http://bonner-ntserver.rice.edu/cms/MS2005_090709.pdf
[3] The CMS Level-1 Muon Trigger Upgrade. TWEPP13 Workshop Plenary talk.
[4] I.Furic. Evolution of the CMS Trigger System. ICHEP 2012, 4-11 July 2012, Melbourne Australia.
[5] D.Acosta et al. Design Considerations for an Upgraded Track-Finding Processor in the Level-1 Endcap Muon Trigger of CMS for SLHC operations. Published in Proceedings of the TWEPP-09. Paris, France, 21-25 September 2009. CERN-2009-006, pp.254-258. 16 November 2009.